# Oceanographic observations at the Amundsen sea shelf break

Conference or Workshop Item

# Oceanographic Observations at the Amundsen Sea Shelf Break

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## Introduction

The continental shelf environment of the Amundsen and Bellingshausen seas differs markedly from that of the other circumpolar seas, where water temperatures are close to the surface freezing point throughout. In the Amundsen/Bellingshausen sector near-freezing temperatures are encountered only in the upper few hundred metres of the water column. Below this surface layer a broad thermocline trends towards upper Circumpolar Deep Water (uCDW), which is found in a form that is almost unmodified from its off-shelf manifestation (Giulivi and Jacobs, 1996). This means that the ice shelves of the Amundsen and Bellingshausen seas experience ocean temperatures some three degrees warmer than those experienced by the other Antarctic ice shelves, and the rates of basal melting are correspondingly high (Jacobs et al., 1996).

In recent years attention has been focussed on Pine Island Bay, in the eastern Amundsen Sea. Two of the largest glaciers draining the West Antarctic Ice Sheet, Pine Island and Thwaites glaciers, discharge into the bay (Figure 1). Pine Island Glacier experiences a mean melt rate in excess of 10 m $yr^{-1}$ (Jenkins et al., 1997; Hellmer et al., 1998), and both glaciers have recently accelerated and thinned (Rignot et al., 2002; Sheppard et al., 2002). The grounding line of Pine Island Glacier appears to be retreating (Rignot, 1998) and surface lowering has been observed in the interior drainage basin feeding both glaciers (Wingham et al., 1998). A similar thinning signature has also been observed near the grounding line of Smith Glacier (Sheppard et al., 2002).

The cause of these changes is far from certain, but the synchronous response of all three floating glacier tongues is more suggestive of a reaction to external forcing than of an internal dynamical change in the glaciers. The most likely external driver of change is the ocean. Hellmer et al. (1998) demonstrated the sensitivity of Pine Island Glacier melt rates to relatively minor changes in water temperature. Clearly any change in the rate of supply or the temperature of the uCDW in Pine Island Bay could have a major impact on the ice shelves there.

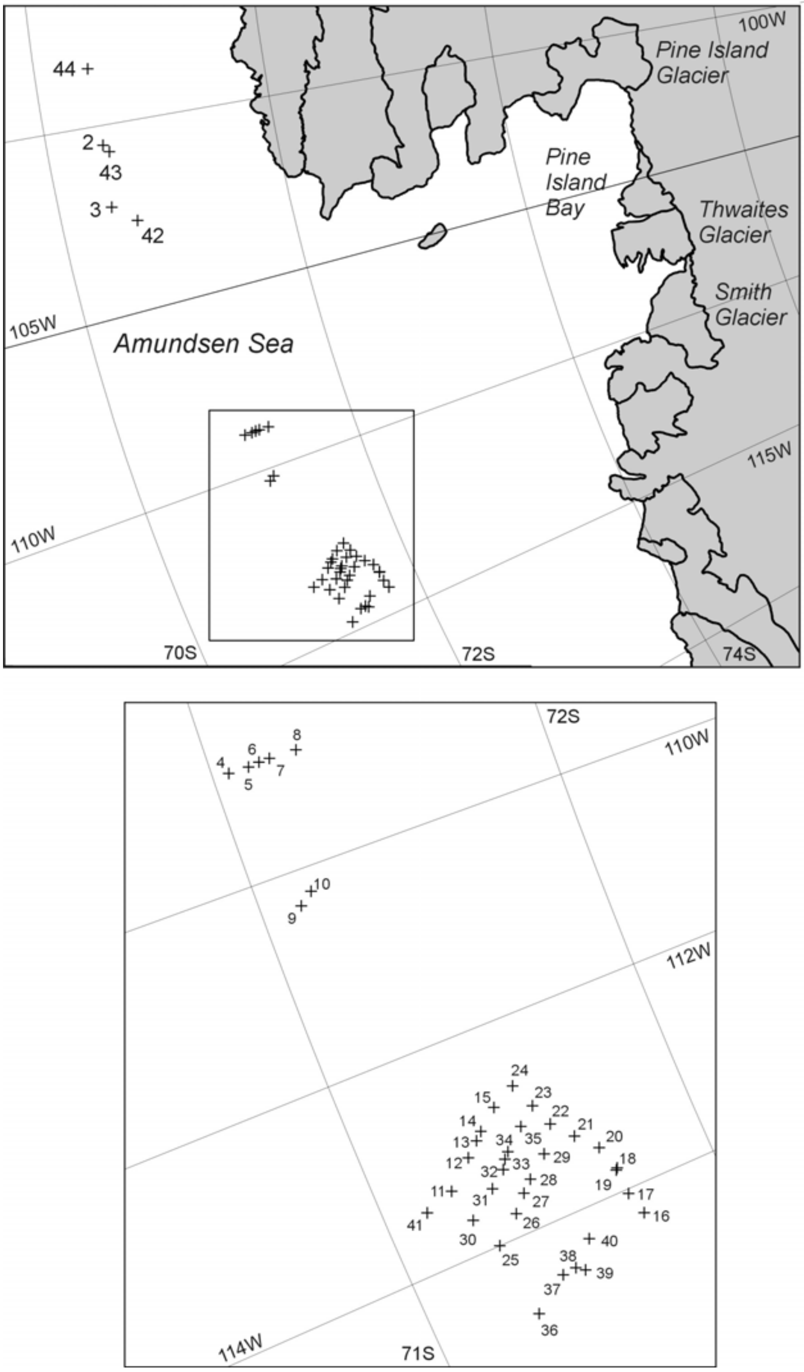


Figure 1: Locations of CTD stations occupied in the eastern Amundsen Sea during JR84. The lower panel is an enlargement of the boxed area in the upper panel.

## Cruise JR84

Cruise JR84 formed the first field campaign of the NERC Autosub Under Ice (AUI) thematic programme. The aim of the programme is to investigate the marine environment of floating ice shelves in Antarctica and Greenland using Autosub, the autonomous submersible vehicle developed at the Southampton Oceanography Centre. The target area for the first cruise, motivated by the need to understand the interactions between ice and ocean there, was Pine Island Bay, with the main focus being Autosub deployments beneath Pine Island Glacier. The planned activities for the cruise included those Autosub missions, as well as deployments beneath the neighbouring glacier tongues (Thwaites and Smith) and under the multi-year sea ice that was expected to be present to the west of the bay. Planned activities for the ship included CTD measurements and swath mapping in Pine Island Bay and the neighbouring continental shelf, as well as measurements on ice floes and the deployment of three Argos beacons in the multi-year pack.

In the event, sea ice prevented the ship getting into Pine Island Bay, so the only under-ice Autosub missions were run beneath multi-year sea ice to the north of Thurston Island (near stations 2, 3, 42–44, shown in Figure 1). Ice floe sampling and the deployment of the drifters were also completed there. The remaining shipboard activities focussed on the Amundsen Sea continental shelf break, the motivation being to investigate how and where uCDW intrudes onto the shelf. In Feb/Mar 2000 a trough was identified at 113–115ºW cutting the shelf break (S. Jacobs, personal communication, 2002) and swath bathymetry data gathered during the most southerly leg of JR84 (during the aborted attempt to access Pine Island Bay) indicated that this trough probably extended all the way to the deep regions of the shelf in front of Pine Island and Thwaites glaciers. Water temperatures observed within this trough in 1994 and 2000 were amongst the highest seen anywhere on the Amundsen Sea shelf. The trough might therefore act as a conduit by which warm uCDW is guided onto the shelf and possibly flows all the way to Pine Island Bay.

## Physical Oceanography on JR84

During the course of the physical oceanography programme on JR84 a total of 44 CTD stations were occupied (Figure 1). The majority of these were arranged in five sections aligned perpendicular to the continental slope and one section parallel to the shelf break approximately 10 km onto the shelf. Most of this work focussed on the seabed trough that cut the shelf break near 113.5°W.

Data from 43 of the stations are shown in the θ/S plot in Figure 2. The main core of uCDW is associated with the potential temperature maximum. The core is generally warmest offshore and cools slightly with progression onto the shelf. However, seaward of the trough two of the sections showed isolated temperature maxima over the upper continental slope (Figure 3) that were separated from the main offshore uCDW core. The isopycnal structure hints at a baroclininc eddy, although a more detailed analysis is needed to confirm this preliminary interpretation. As the uCDW core cools, its trajectory on the θ/S plot is towards the salinity maximum (Figure 2). This implies that the cooling is effected more by mixing with lower CDW than with the overlying thermocline waters, and suggests that mixing in the bottom boundary layer over the upper continental slope is important in dictating the properties of the uCDW that intrudes onto the shelf. The lower CDW core is found near 1000 m depth, considerably deeper than the shelf break even in the trough (where the shelf break reaches a maximum depth of around 620 m). If waters from greater depths contribute to the on-shelf flow, the cause may be upslope flows within the bottom boundary layer, associated with either the mixing or with the larger-scale flow.

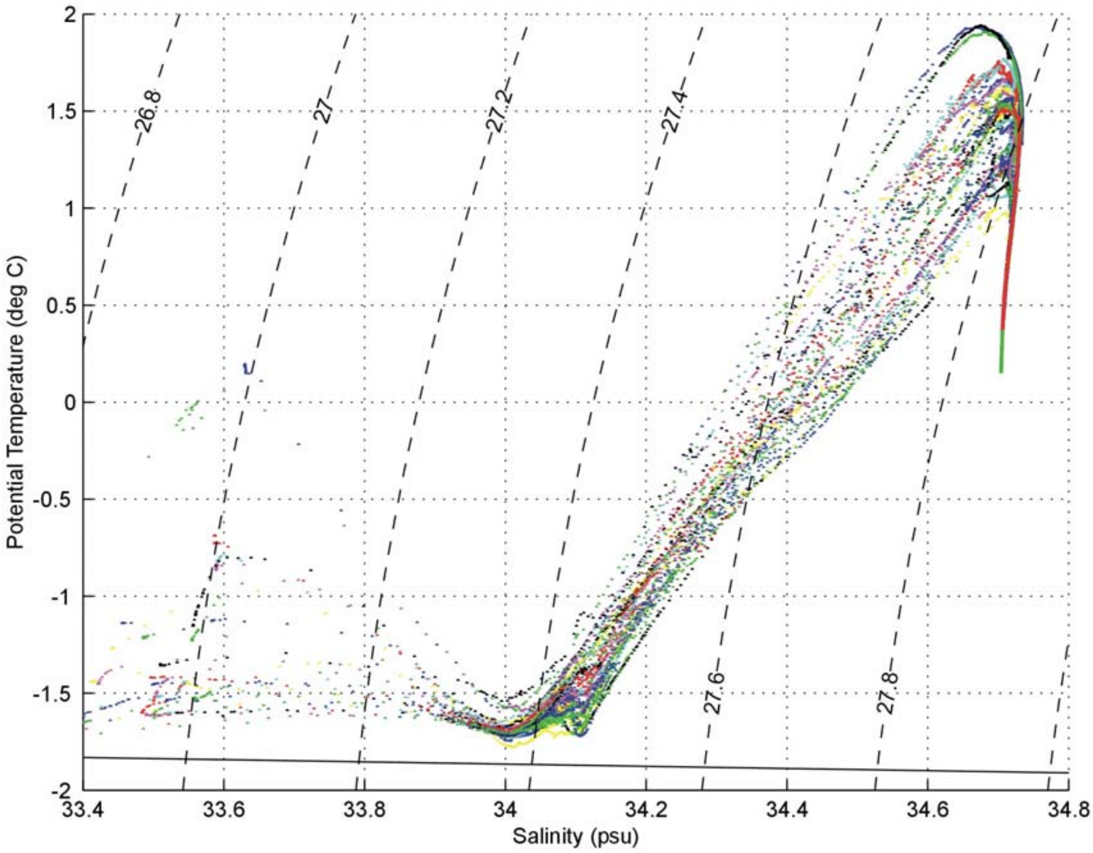


Figure 2: Scatter plot of potential temperature versus salinity data from CTD stations 2 to 44. The solid black line indicates the surface freezing point, and the labelled, dashed lines are isopycnals referenced to surface pressure.

The CTD section across the trough clearly delineated a warm tongue extending along the eastern flank (Figure 3). Temperatures in excess of +1.4°C within this core are the highest yet observed on the Amundsen Sea continental shelf. These observations suggest that the trough plays some role in permitting or promoting the flow of uCDW onto the shelf. It is possible that the topography of the shelf break disturbs the larger-scale flow, driving the on-shelf transport and perhaps generating the eddy-like feature over the upper slope. It is also possible that the nature of the continental slope seaward of the trough, where a series of deep gullies is incised into the slope, plays a key role in the process. It is likely that mixing in the bottom boundary layer is greatly enhanced over the gullies. The data presented here, along with the continuously recorded ADCP and meteorological records should help us to clarify the factors that dictate the magnitude and variability of the heat supplied by the uCDW intrusions into Pine Island Bay.

## Future Work

The analysis of the physical oceanography data collected during JR84 is still at an early stage, but we hope that in the future we will be able to provide answers to the following questions:

- How large is the on-shelf transport of uCDW within the trough?

- What rates of basal melting can the associated heat transport sustain?
- How do the large-scale flow and topography combine to allow or enhance the on-shelf flow?
- What could cause the on-shelf transport to change?
- What changes in basal melting would this cause?

With answers to these questions we will have taken a major step towards clarifying whether oceanic forcing could be responsible for the observed changes in the ice sheet inland of Pine Island Bay.

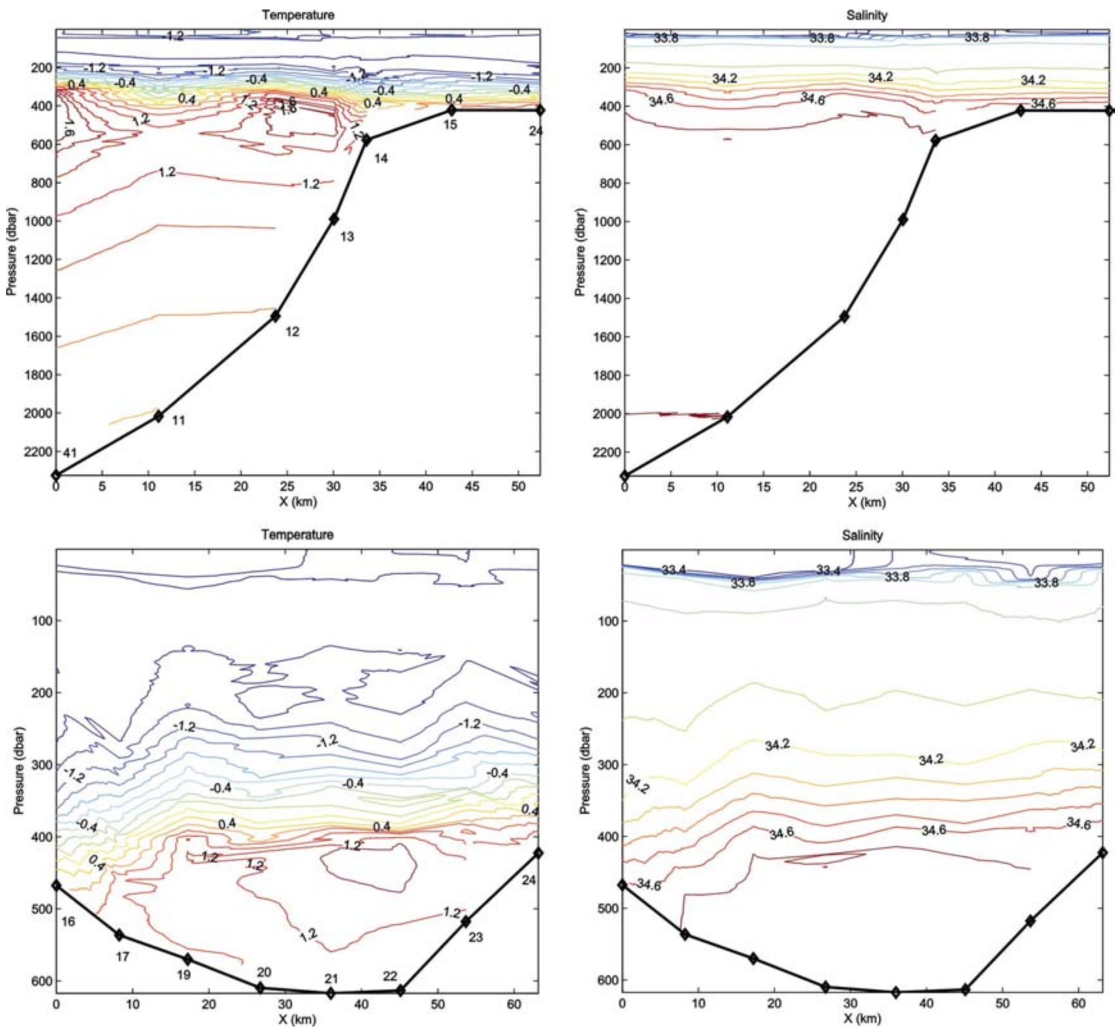


Figure 3: Potential temperature (left) and salinity (right) sections measured perpendicular (top) and parallel (bottom) to the shelf break. Individual stations are indicated by the diamonds (numbered on the temperature sections) marked along the seabed.

**Acknowledgements:** We are grateful to the officers and crew of RRS James Clark Ross for all their efforts during JR84. We would also like to thank Stan Jacobs for providing us with unpublished data obtained in this region in 1994 and 2000.

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